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(RESEARCH ARTICLE)

Effect of UV-B stress on stomatal pore size and pore width in some landscape plants

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Abstract

It is known that global climate change is an irreversible process and will directly or indirectly affect all living things in the world. It is estimated that the most devastating effects of the process will be seen on plants and, especially, woody species that do not have a long life cycle. Therefore, being prepared for the process, determining the extent to which species will be affected, and taking precautions are of great importance in terms of preventing individual, population, and even species losses. This study determined the effects of the increase in UV-B, one of the process's most important effects, on stomatal pore length and pore width. Within the scope of the study, UV-B treatments were made to 10 woody broad-leafed plants at 4 different intensities. At the end of the treatments, leaf samples were obtained from tree species, and images were then taken to scale with the help of an SEM (scanning electron microscope), and stomatal pore length and width were measured. The study results show that the treatments do not significantly affect these characters. However, it is also known that the most important effects of global climate change will be temperature increase and drought. Therefore, it is recommended that similar studies be conducted by including drought stress.

Keywords: Ultraviolet-B; Stomata; Climate Change; Radiation; Ozone

1. Introduction

The industrial and technological developments that have increased significantly in the last century and peaked in the last 30-40 years have caused a process that has permanently affected almost all living things in the world. Many researchers agree that the most important of these changes are global climate change [1-5], urbanization [5-10] and environmental pollution [11-15]. Moreover, these problems are global and interconnected. For example, the industrial revolution experienced in the last century in the industry field has created a significant need for raw materials, energy, and labor. The job opportunities created by the industry have triggered migration from rural areas to urban areas, causing the population to gather in certain areas, and thus, the problem of urbanization has emerged [16]. Using fossil fuels to meet energy needs has also significantly increased the CO_2 rate in the atmosphere and accelerated the global climate change process [17-18]. In addition, urbanization requires more people to live in a unit area. In order to meet this, the construction of high-rise buildings in limited areas is mandatory. Concrete production used in the construction of high-rise buildings uses approximately 18% of global annual industrial water use. It is also stated that approximately 10% of global carbon dioxide (CO2) emissions originate from cement production, the primary material for concrete production [19-28]. As a result, urbanization, global climate change, and environmental pollution, which have emerged due to industrial and technological developments, have become interconnected problems affecting the global scale [16, 18, 29-32].

This situation threatens the health and even the lives of many living beings. Industrial activities, especially anthropogenic wastes, have accumulated significantly in water [33-35], soil [36,37], and air [38-41], causing pollution

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and becoming a threat to life. For example, it is stated that air pollution causes approximately 6 million premature births, approximately 3 million low-weight babies, and approximately 7 million premature deaths worldwide every year [18,42].

Another of these problems, the consequences of global climate change, are much more serious. Global climate change is defined as the biggest problem the world has to overcome [2,5,43]. Because climate directly or indirectly affects all living things in the world [1,4]. Animals can adapt to these changes to a large extent by migrating to regions where climatic conditions are suitable. It is emphasized that the living group that will be most affected by global climate change will be plants that do not have an effective movement and migration mechanism, especially woody species with long life cycles [2-5].

It is stated that global climate change is irreversible, can only be slowed down by taking precautions, and that the process must be prepared. Various scenarios are being developed to determine the changes that may occur in this process, and efforts are being made to determine the possible changes in advance and the precautions that can be taken [1,4]. Determining how trees will be affected by this process is of great importance in terms of determining the precautions to be taken and protection strategies.

Among the most consequential impacts of global climate change, drought [44-46], and elevated UV-B radiation [47] emerge as particularly detrimental to terrestrial ecosystems. The stratospheric ozone layer (10-30 km altitude), which undergoes progressive thinning due to climate change, represents a critical planetary life-support system. This depletion allows enhanced penetration of biologically harmful UV-B wavelengths (280-320 nm) to Earth's surface [48], constituting one of the most severe environmental threats. Empirical studies demonstrate that amplified UV-B exposure significantly impairs plant development, manifesting as reduced stem diameter, diminished height, decreased leaf production, and lower biomass accumulation [47,49], while additionally disrupting phenological cycles [50]. Importantly, these physiological responses exhibit substantial interspecific variation, necessitating species-specific investigations to characterize UV-B impacts across diverse flora accurately.

This study aims to determine the invisible effects of UV-B radiation in some woody species and how stomatal pore length and pore width are determined from leaf stomatal characters in plants exposed to increased UV-B treatments in a controlled environment.

2. Materials And Method

The study was conducted on 10 broad-leaved woody species, which are the most preferred in landscape studies in our country. The list of species used in the study is given in Table 1.

Table 1 Species subject to the study

Species label	Full name of species
SP1	*Cotoneaster franchetti*
SP2	*Laurus nobilis*
SP3	*Ginkgo biloba*
SP4	*Betula pendula*
SP5	*Cornus mas*
SP6	*Prunus laurocerasus*
SP7	*Lagerstromia indica*
SP8	*Hibiscus syriacus*
SP9	*Buddleja davidii*
SP10	*Forsythia viridissima*

The study was conducted on two-year-old seedlings. A cabin with a base area of 3 m x 3 m and a height of 2 m was prepared for UV-B treatment. The inner surfaces of the UV-B treatment cabin were covered with 12-micron aluminum foil to prevent leakage from outside to inside and from inside to outside. 4 Philips 40w/12 RS broadband UV-B lamps were placed inside the cabin for the UV-B source.

The treatment period was determined for each dose applied within the scope of the study, and 4 different UV-B treatments were performed as low, medium, high, and very high. Thus, 5 different treatments (control [no UV-B], low, moderate, high, and very high) were performed together with the control group. Treatments started in July and were made every 3 days for 45 days. The leaves formed after the treatments were taken for SEM image analyses. Scaled images were taken from the lower surface of the leaf blade and from the places close to the middle parts of the leaves pressed and brought to the laboratory under the electron microscope. The "ImageJ" computer measurement program was used to perform pore length and pore width measurements. Within the scope of the study, measurements were made with 5 replications. The data obtained from the study were evaluated with variance analysis and the Duncan test with the help of the SPSS package program.

3. Results

The obtained data were simplified and tabulated by applying variance analysis and the Duncan test. Stomatal pore width differences among species depending on the treatments are given in Table 2.

Table 2 Stomatal pore width differences among species depending on the treatments

Species	Control	Low	Moderate	High	Very high	F-value	Average
SP1	6.27 BC	4.57 A	4.90 AB	5.73 CD	4.91 AB	1.541 ns	5.27 AB
SP2	7.57 aC	7.60 aA	11.10 bC	6.33 aDE	7.49 aCD	5.355**	8.02 CD
SP3	4.40 aAB	15.78 bB	13.22 bC	5.20 aBCD	3.42 aA	37.023***	8.40 D
SP4	6.92 bC	3.75 aA	6.29 bB	4.00 aABC	12.60 cE	52.651***	6.71 BCD
SP5	10.38 bD	2.74 aA	3.19 aA	3.12 aA	9.31 bD	19.918***	5.75 AB
SP6	7.45 C	6.78 A	5.39 AB	7.64 E	5.93 BC	2.693 ns	6.64 BCD
SP7	6.98 cC	4.27 aA	3.36 aA	3.54 aAB	5.35 bAB	18.301***	4.70 AB
SP8	3.43 A	4.82 A	4.06 AB	4.70 ABCD	4.56 AB	0.757 ns	4.32 A
SP9	7.17 C	7.15 A	4.82 AB	4.39 ABC	7.56 CD	2.726 ns	6.22 ABC
SP10	4.18 A	12.52 B	4.21 AB	4.50 ABC	5.32 AB	2.659 ns	6.15 ABC
F-value	8.654***	6.293***	16.253***	6.416***	16.081***		4.030***
Ave.	6.67 b	7.00 b	6.06 ab	4.91 a	6.65 b	2.805*	

Note: ns: not significant; *: p≤0.05; **: p≤0.01; *: p≤0.001. Lower-case letter specifies to the vertical way within each row, whereas upper-case letter implies to the horizontal way within each column. These explanations are also valid for Table 3.

When pore width differences are examined, it is seen that the changes are statistically significant on a species basis in all treatments. However, the change due to the treatments is not statistically significant in species 1, 6, 8, 9, and 10. The lowest average value was obtained in the intense UV-B treatment, and no statistically significant difference was found between the other treatments. Stomatal pore length differences among species depending on the treatments are given in Table 3.

Table 3 Stomatal pore length differences among species depending on the treatments

Species	Control	Low	Moderate	High	Very high	F-value	Average
SP1	19.01 ^{DE}	16.97 ^{CD}	18.73 ^{CD}	16.99 ^{C}	16.37 ^{CD}	1.313 ns	17.62 ^{C}
SP2	20.32 ^{E}	17.12 ^{CD}	20.67 ^{D}	18.25 ^{C}	19.12 ^{DE}	2.411 ns	19.10 ^{CD}
SP3	16.20^{bBCDE}	29.50 ^{dE}	22.99 ^{cD}	16.40 ^{bC}	9.23 ^{aA}	54.676***	18.86 ^{CD}
SP4	19.16 ^{abDE}	20.19 ^{bD}	22.26 ^{bcD}	14.43 ^{aABC}	26.91 ^{cF}	6.715**	20.59 ^{D}
SP5	17.89 ^{bCDE}	9.69 ^{aAA}	8.42 ^{aA}	11.54 ^{aAB}	22.07 ^{bE}	10.353***	13.92 ^{B}
SP6	19.00 ^{bDE}	12.90 ^{aABC}	12.06 ^{aAB}	15.10 ^{aBC}	13.37 ^{aBC}	4.504**	14.48 ^{B}
SP7	10.29 ^{A}	12.44 ^{AB}	9.67 ^{A}	10.51 ^{A}	11.89 ^{AB}	1.165 ns	10.96 ^{A}
SP8	12.37 ^{abAB}	16.10 ^{cBCD}	14.54 ^{abcBC}	15.55 ^{bcBC}	11.98 ^{aAB}	3.214*	14.11 ^{B}
SP9	15.14 ^{BCD}	13.83 ^{ABC}	12.51 ^{AB}	16.21 ^{C}	16.91 ^{CD}	0.877 ns	14.92 ^{B}
SP10	13.78^{abABC}	10.08 ^{aA}	14.70 ^{bcBC}	14.22 ^{abcABC}	18.28 ^{cD}	4.481*	14.21 ^{B}
F-value	5.720***	18.060***	11.390***	3.317**	19.180***		11.509***
Ave.	16.32	15.88	15.66	14.92	16.61	0.782 ns	

As seen in Table 3, pore length differences vary statistically significantly on a species basis in all treatments. However, the change due to the treatments is not statistically significant in species 1, 2, 7, and 9. Similarly, regarding average values, the change in pore size depending on the treatments is not statistically significant.

4. Discussion

As a result of the study, it was determined that stomatal characters changed significantly on a species basis. However, the effect of UV-B treatments on stomatal characters was not significant and at the expected level. Different results were obtained in the studies conducted on this subject. It was determined that UV-B radiation increased stomatal pore size in ash-leaved maple species while it decreased it in mountain maple. Stomatal pore width was observed to have the lowest values in individuals exposed to severe drought and high dose UV-B simultaneously in ash-leaved maple species [47].

When the studies are examined, it is seen that the effects of UV-B stress on plant stomatal characters remain unclear. It is necessary to examine whether this situation depends on the species or varies according to the treatment. Plant phenotypic characters are shaped under the interaction of genetic structure [51-54] and environmental conditions [55-67]. Stomatal characters are also significantly affected by environmental factors as well as genetic structure. In addition to changes in atmospheric conditions, changes in edaphic factors such as soil moisture and nutrient status have been found to alter stomatal morphology [47, 68, 69]. Plant stomata, the vital gateway between the plant and the atmosphere, may have a central role in plant/vegetation responses to environmental conditions, which have been investigated from molecular and whole plant perspectives as well as ecosystem and global levels [70]. Consequently, both the exposure pattern (duration and intensity) and spectral composition of UV-B radiation fundamentally influence plant morphological traits and growth architecture. These relationships are mediated through complex stress response mechanisms that plants have evolved, including photoprotective pigment accumulation and antioxidant systems [71,72]. Current research demonstrates substantial context-dependence in UV-B effects, with plant responses being modulated by concurrent environmental factors such as water availability, temperature regimes, and light quality [73]. It is stated that UV-B radiation significantly affects the invisible micromorphological characters of plants and their morphological characters [74]. Micromorphological characters indicate the plant's response to stress factors. However, many studies on this subject show that the interaction of many factors shapes micromorphological characters such as stomatal characters [75-78].

The most important of these factors are genetic structure and environmental factors. It is stated that even plants of the same species grown in the same environment are affected by stress factors at different levels due to their different genetic structures [79-84]. In addition, environmental conditions, i.e., climatic and edaphic factors, significantly affect plant development [85-88]. It is known that climate conditions are particularly decisive in plant morphological, anatomical, and physiological characteristics and plant responses to stress levels [1,4,5]. However, studies have shown that microecological conditions are more effective in the primary climate type [75,76,89]. Plant responses to stress factors are also influenced by factors that change microecological conditions. Various practices such as irrigation, fertilization, hormone treatments, pruning, and shading can change plant responses to stress factors [90-92]. As a result, the responses of plants to environmental stress factors, including UV-B stress, are influenced by many interrelated factors, and many points have not yet been clarified.

5. Conclusion

This study investigated the effects of increased UV-B radiation on stomatal pore length and pore width in ten commonly used broad-leaved woody landscape species. While interspecific differences in stomatal traits were statistically significant, the UV-B treatments alone did not lead to substantial changes within species. These findings suggest that the stomatal response to UV-B stress is not uniform and may be influenced by species-specific genetic and environmental interactions. Given that global climate change is irreversible, and its most destructive effects are expected on plant species—especially long-lived woody plants—proactive strategies are essential to assess species resilience and guide urban landscape planning. Since temperature rise and drought are among the most critical stressors associated with climate change, future research should incorporate multiple stress factors, particularly drought, to more accurately reflect natural conditions. This study contributes valuable data for identifying climate-resilient species and offers a foundation for further research that supports biodiversity conservation and sustainable green space management in the face of changing global conditions.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in this study.

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